TOPOGRAPHIC MAPS

By

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Part I

Topographic Maps; Their Character and Use

THE purpose of this article is to acquaint the reader with the character and uses of topographic maps.

Each year brings an increasing demand for topographic maps from hunters, fishermen, vacationers and land owners, as well as professional engineers. The personnel of our armed services became very familiar with the topographic maps as an instrument of war. Civilian use of these maps by veterans has contributed substantially to the tremendous expansion of demand for maps since World War II.

Systematic mapping of topography in the United States was begun by the U. S. Geological Survey before the turn of the century to meet the needs for base maps necessary in its geologic mapping program. The preparation of topographic maps has remained a function of the U. S. Geological Survey, cooperating in many cases with state agencies. In Pennsylvania these maps are prepared by the U. S. Geological Survey, cooperating with the Bureau of Topographic and Geologic Survey of the Department of Internal Affairs. ([1])

The topographic map is a tool of fundamental importance to the geologist, the forester, and the soil conservationist. It is also widely used by the engineer in planning highways, dams, utility transmission lines, radio and television stations, plant layouts, and a host of other construction projects. More laymen are learning each day of the advantages of topographic maps in the pursuit of both business and pleasure.

Fundamental Concepts

Topography is the configuration of the land surface. The topography of any land surface may be shown diagrammatically at a reduced scale on a *topographic map*. This map will show the location of hills, valleys, streams, lakes, and other features contributing to land form. It may also employ conventions to show roads, houses, and other cultural features. In addition to showing the horizontal position of land forms and cultural features, the topographic map shows *relief*, or vertical relationships, of these features. The shape and character of land forms is portrayed on topographic maps (see figure 1).

Types of Topographic Maps

Topography may be shown on maps by a number of methods. The most vivid expression of topography can be obtained in the relief map (or model) which shows the actual configuration of the land surface in

[1] An index to topographic maps of Pennsylvania will be sent on request by the Topographic and Geologic Survey, Department of Internal Affairs, Harrisburg, Pa.

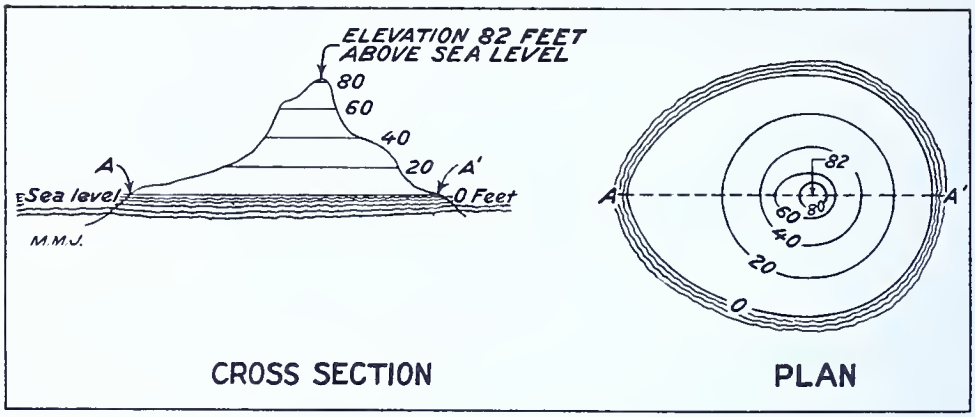

Figure 1. A small island is shown in cross section (side view) and in plan (top view) to illustrate contour lines. The *contour line* represents an imaginary line drawn on the ground through all points of equal elevation. In the cross section above contours have been drawn at intervals of 20, 40, 60, and 80 feet above sea level; the top of the hill has an elevation of 82 feet above sea level. The plan view (looking down from above) shows the same island with the same contour lines encircling the island at 20-foot intervals.

three dimensions. To accentuate topography, the vertical scale is usually exaggerated on these maps. Relief models may be constructed from plaster, modeling clay, plastic, rubber, or other material. Figure 2 is a photograph of a plastic relief model made from a topographic map of the Harrisburg quadrangle. Relief models, though they depict topography

Figure 2. Photograph of a plastic relief model showing the Susquehanna Gap area north of Harrisburg. This relief model was constructed using the U. S. Geological Survey topographic map of the Harrisburg quadrangle as a base, so that contour lines are shown in addition to actual relief.

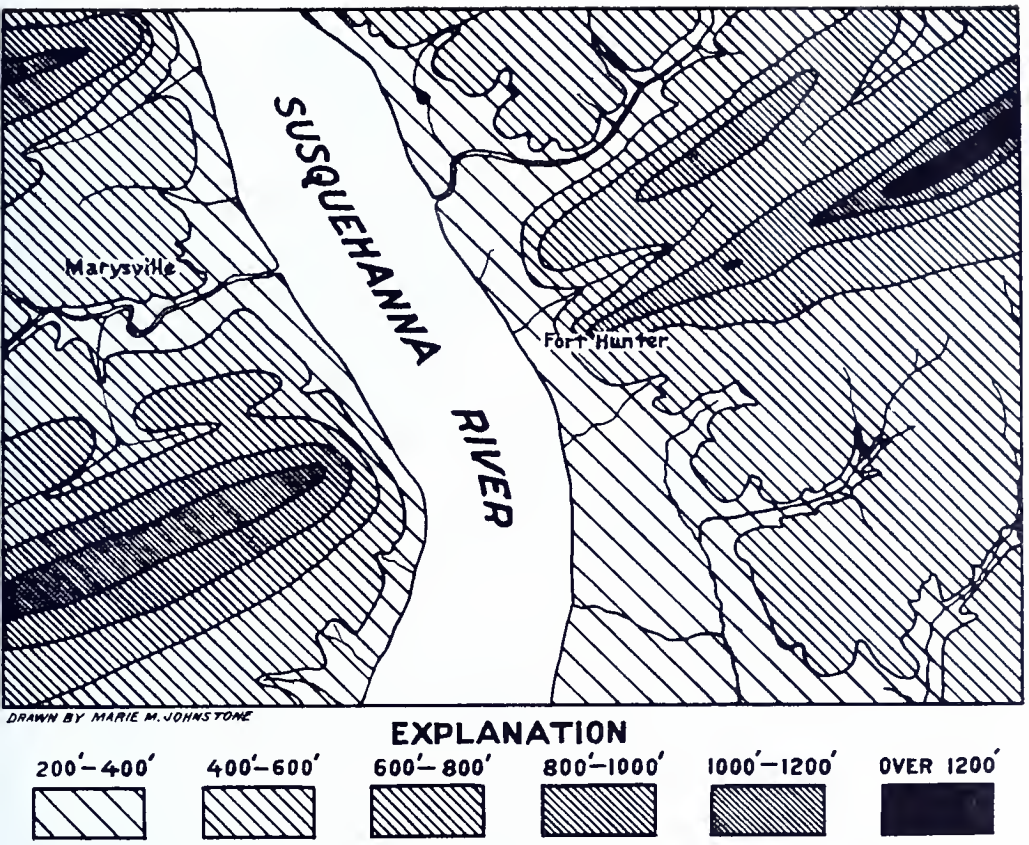

Figure 3. Map of the Susquehanna Gap area north of Harrisburg, showing the topography by shading.

in an excellent visual manner, are less versatile, more cumbersome, and much more expensive than topographic maps which are usually drawn or printed by conventional means.

On a plane (flat) map surface, topography is commonly shown by one of three methods: 1. shading, 2. hachures, 3. contours.

Shading. A very generalized, but graphic, idea of relief may be obtained by shading areas of different elevations (Figure 3). This method is commonly employed on small scale maps of states, countries and continents to delineate mountain ranges, river valleys, and other prominent topographic features. Geography texts and atlases usually show topographic relief by degrees of shading, with the lowlands in green and the highlands in brown. Aeronautical charts used by present-day pilots employ shading as a visual means of representing topography. Almost everyone is familiar with this representation of topography in one form or another.

Hachures. Differences in elevation may be shown by hachures, or lines, running in the direction of the slope (Figure 4). The steeper the slope being portrayed, the closer the hachure lines are spaced. By this technique, the shape of land forms can be depicted in a realistic manner. Hachure maps have been utilized to a much greater extent in Europe than in the United States. Though more realistic than the representation of relief by shading, the hachure map is much less accurate than the contour map.

Figure 4. Map of the Susquehanna Gap area north of Harrisburg, showing the topography by hachures.

Contours. The use of contours is the most satisfactory means of expressing relief on a map. This method is used by the U. S. Geological Survey in preparing topographic maps. A *contour line* is a line drawn on a map through all points of equal elevation. It represents an imaginary line drawn on the ground through all points of equal elevation (Figure 1). On the topographic maps prepared by the U. S. Geological Survey, all elevations are measured with respect to mean sea level. Should a contour line be drawn 10 feet above sea level in a coastal area, this line would delineate the new shore line if there was a 10-foot rise in the level of the sea.

Contours show the shape and character of valleys, hills, and mountains (Figure 5). Widely spaced contour lines indicate a land surface which is relatively flat or gently sloping. Where hills are steep, the contours are closely spaced; in steep cliffs, they merge. Contour lines show not only the configuration of the land surface, but also the relative elevations of mapped features above sea level. On the topographic map, roads may be traced as they rise over hills depicted by contours. The approximate elevation of houses and other cultural features can also be determined. In addition to contour lines, the usual topographic map carries many spot elevations, accurate to the nearest foot, on bench marks, road intersections, lake surfaces, and topographic prominences.

The contour line is used to portray land forms on the topographic maps of the U. S. Geological Survey. Most commonly in the eastern United States, the interval between contours is 20 feet; that is, a contour line is drawn at each 20-foot interval of elevation above mean sea level. In Pennsylvania the lowest contour is the 20-foot (above sea level) along

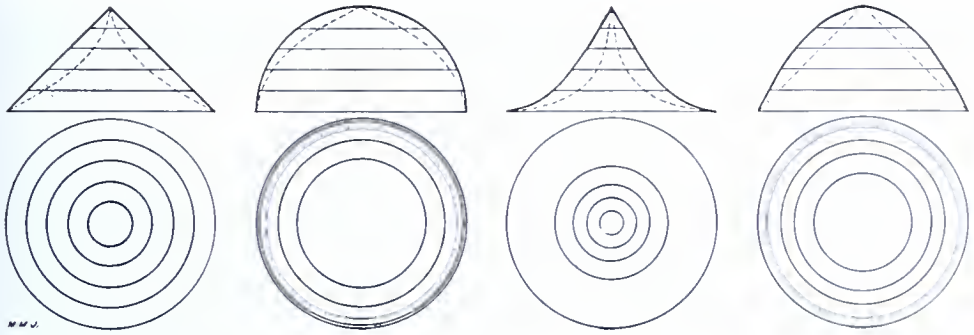

Figure 5. Spacing of contour lines portrays surface characteristics. Contour lines have been drawn at equally-spaced vertical intervals on four geometric forms shown in cross section (top). In the plan view (bottom), that is, looking down from above, the spacing of the contours varies greatly depending upon the shape of the geometric form. By permission from GENERAL CARTOGRAPHY, by Erwin Raisz, Copyrighted 1938, by McGraw-Hill Book Company, Inc.

the Delaware River at Chester; the highest on Negro Mountain in southern Somerset County, where a 3,200-foot contour delineates the highest point in the State.

Contour lines are shown in brown on U. S. Geological Survey maps, streams and lakes in blue, and culture and map names in black.

Figure 6 shows a portion of the topographic map of the Harrisburg Quadrangle in the vicinity of Susquehanna Gap. This same area is shown by shading and hachures in Figures 3 and 4. By comparison of the three

Figure 6. Map of the Susquehanna Gap area north of Harrisburg, showing topography by contours. This map is a portion of the U. S. Geological Survey topographic map of the Harrisburg quadrangle. The identical area is depicted by shading (Fig. 3) and hachures (Fig. 4) for comparison.

illustrations of the same area, one is able to recognize the obvious advantages of the contour map. The contour map combines accuracy and versatility not found in other topographic maps.

Horizontal Scales of Maps

In discussing contour lines and contour intervals used in topographic map making, no mention has been made of the horizontal scale of the maps. First of all, Pennsylvania (and the United States) was subdivided by the U. S. Geological Survey into quadrangles embracing 15 minutes of latitude and 15 minutes of longitude. These quadrangles, usually designated by the name of a prominent town or physiographic feature found within their borders, have served as a basis of division in systematic topographic mapping.

The horizontal scale most commonly used in preparing maps of the 15-minute quadrangles has been 1:62,500 (1 inch on the map is equivalent to 62,500 inches on the ground), or, for practical purposes, 1 inch equals 1 mile. Most of the topographic maps available for Pennsylvania are of 15-minute quadrangles having a 1:62,500 horizontal scale and a 20-foot contour interval (Figure 6).

In recent years, the quality of topographic maps has been greatly improved by refinements in methods and by the use of aerial photography in map compilation. This advancement, coupled with an ever-increasing demand from engineers, geologists, and many others for more detailed maps, has resulted in the current practice of issuing new topographic maps covering 7½-minute quadrangle areas at a scale of 1:31,680 or 1:24,000. Four 7-½minute quadrangles constitute a 15-minute quadrangle. Figure 7 compares graphically the scales of the U. S. Geological Survey topographic maps covering Pennsylvania. The scale 1:31,680 (2 inches equals 1 mile) was originally adopted by the U. S. Geological Survey for the 7½-minute quadrangles, but is being replaced in most states by the 1:24,000 (1 inch equals 2,000 feet) scale because of its engineering advantages. Those portions of Pennsylvania which have not as yet been mapped are being completed in 7½-minute units to the scale of 1:24,000. It is also anticipated that these maps which have already been published in the State at the scale of 1:31,680 will be converted to the 1:24,000 scale as subsequent editions are printed.

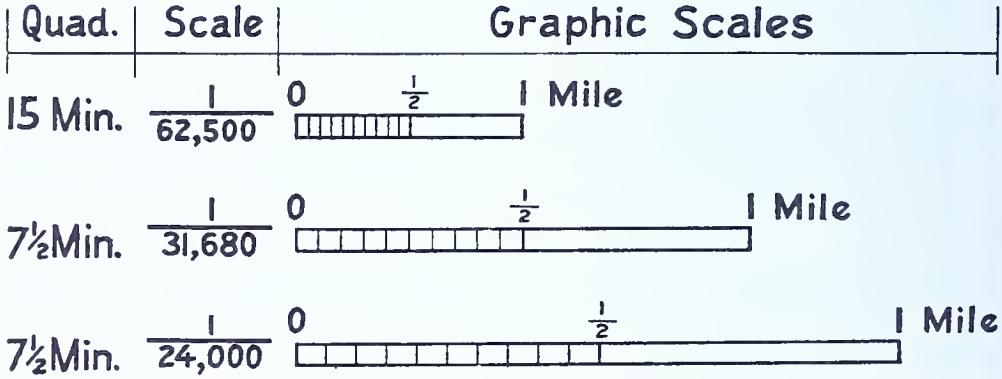

Figure 7. Comparison of scales used in U. S. Geological Survey topographic maps covering Pennsylvania. With a scale of 1:62,500, one inch equals approximately one mile; 1:31,680, two inches equals one mile; and 1:24,000 one inch equals 2,000 feet.

Part 2

Highlights from History of Topographic Mapping

THE history of topographic mapping by the United States Geological Survey actually began about 1850, some thirty years prior to the passage of the act that created the Survey in 1879. Events which took place during this thirty-year period culminated in the formation of the U. S. Geological Survey.

During the 1850's, following the discovery of gold in California, westward movement into the vast territories west of the Mississippi River was in full swing. Reconnaissance surveys were undertaken by expeditions under direction of the U. S. Army, Corps of Topographical Engineers, to seek likely routes for transcontinental rail lines. Surveys followed the 35th, 40th, and 46th parallels. These surveys, interrupted by the Civil War, were resumed immediately following the end of hostilities. The principal objective of the reconnaissance surveys was first realized at Promontory Point in Utah on May 2, 1869, when a golden spike was driven to unite the Union Pacific, building from Omaha westward, and the Central Pacific, building eastward from Sacramento.

About the time the first transcontinental railroad was completed, a need was recognized for greater scientific and topographic data to aid in the development of the vast western area. Led by masterful organizers, four independent geologic and geographic surveys were formed. These were:

1. The Geological and Geographic Survey of the Territories (1867-1879) led by Professor Ferdinand V. Hayden, under the Department of the Interior.

2. The Geographical Surveys west of the 100th Meridian (1868-1879) led by Captain George M. Wheeler, C.E., under the War Department.

3. The Geographical and Geological Survey of the Rocky Mountain Region (1869-1879) led by Major John W. Powell, under the Smithsonian Institute.

4. The U. S. Geological Exploration of the 40th Parallel (1871-1879) led by Clarence King.

The surveys competed actively for governmental appropriations and also for the scientific occupation of the most attractive areas in the West. The National Academy of Science, seeking to eliminate wasteful duplication of time and effort, petitioned Congress with a plan which culminated in the formation of the U. S. Geological Survey, for the purpose of classifying public lands and examining the geology and mineral resources of the United States.

Invariably, the bed rock formations of an area play a very significant part in controlling the shape of the land surface, the topography. For this reason good topographic maps are invaluable to the geologist in field mapping. The needs of the geologist of the newly-formed Geologic Survey, as well as other scientists and engineers aiding in the development of the Western frontiers, led to the formulation of a nation-wide topographic mapping plan by Clarence King, the first director.

Romance and Adventure

These pioneer days in topographic mapping were rich in romance and adventure. The daily journals of the early surveys could furnish abundant color for the novelist and movie-writer. Survey parties were constantly braving the dangers of the uncharted wilderness, climbing mountains, exploring canyons.

The topographers travelled by wagon, horse-back, or a-foot while traversing these unmapped regions. Their home was a camp outfit that might be set up beside a water hole or well in desert country, or beside a stream or pool among the pines of a mountain slope. It was not uncommon that their work was temporarily suspended to establish friendly relations with Indian tribes, and there were occasions when hostile Indians threatened the safety of the field parties. The life of the early topographer was indeed rigorous, but it was with great pride that they expended themselves to the maximum to accomplish the herculean tasks before them. The hardships of this geographical conquest were offset by the pleasures that come only from out-of-door living and by the stimulation of new horizons to conquer.

In the earliest days of the U. S. Geological Survey, topographic mapping was carried out using methods which gave, at the best, a reconnaissance map.

To survey a given area, the initial ground position was determined by astronomical observations, using the theodolite. From this point a base line was extended and the horizontal location of prominent land features was determined by triangulation. Elevations were determined by mercurial barometers. Roads, streams, and distances between points were measured by counting the paces of horse or man. The number of revolutions of a wagon wheel was also employed as a means of measuring distance. The engineer occupying triangulation stations would sketch in his notes the surrounding terrain. Copious notes were also taken while travelling from one station to the next. In the office, during winter months, the engineer would fill in the topography from his field notes on the basic network of triangulation points, compiling either a hachure or contour map. The methods were far from exacting, and the accuracy of the maps reflected, to a large extent, the ability of the individual topographer.

The quality of the scientific work in these frontier regions depended greatly upon the accuracy of the base maps; the quantity on the speed with which these maps could be made available. For this reason, the theodolite method of collecting topographic data, involving voluminous notes and sketches, was discarded during the early days of the U. S. Geological Survey for the plane table-alidade method of mapping. By this method the topographic data could be placed directly on the map

Figure 8. A topographic engineer using the plane table and alidade in preparing a topographic map. The plane table is a tripod-mounted drawing board, and the telescopic alidade is an engineering transit adapted for use with the plane table. Photograph by courtesy of the U. S. Geological Survey.

in the field, thus increasing the accuracy and obviating much time-consuming note-taking.

Plane Table and Alidade

Plane table is the name given to a drawing board which is fastened by an adjustable mounting on a surveyor's tripod. The main advantage of the plane table as field instrument is that the map being prepared can be drawn directly upon the map sheet attached to the drawing board. The *telescopic alidade* is an adaptation of the surveyor's transit for use with the plane table. The alidade has a flat metal base upon which the instrument rests on the plane table surface. Figure 8 shows the plane table and telescopic alidade.

The plane table and alidade are considered essential instruments to topographic and geologic mapping, primarily because they permit the construction of the map in the field. After "shooting in" critical points on roads, streams, and topographic or geologic features, the mapper can sketch, with considerable accuracy, the intervening details without relying on memory or notes. The U. S. Geological Survey, as a principal user of topographic mapping instruments, has contributed many of the improvements in the design of present-day telescopic alidade.

Plane Coordinate System

The U. S. Geological Survey has not been working alone in its topographic mapping efforts. The Lake Survey, the U. S. Army Engineers, and the General Land Office are among the federal government agencies that contributed to the program. The greatest supporting contribution has been made, however, by the U. S. Coast and Geodetic Survey in supplying the primary horizontal and vertical control necessary for topographic mapping.

The U. S. Coast and Geodetic Survey triangulation network serves as a basis for the Plane Coordinate System as well as for topographic map control. The Coast and Geodetic Survey has constructed systems of plane coordinates for each state. By the use of these systems geographic positions can be converted to plane coordinates. Survey stations tied to the system are definitely located with respect to latitude and longitude.

Property surveys are usually referenced to a stake, tree, or some other local landmark which may disappear or be moved with the passing of the years. Many thousands of dollars are spent annually surveying and resurveying these poorly referenced property boundaries. Surveys for highways, public works, and plant sites invariably originate from some temporary arbitrary reference point. In order that repeated confusion and duplication of effort be reduced to a minimum, it is desirable that all important engineering surveys be adjusted and referenced to a common framework. The coordinate grid may be placed on topographic maps as an aid in making map locations.

Land surveyors and civil engineers responsible for construction planning alike are heartily in favor of the adoption of plane coordinates, for they seek uniformity and accuracy in their survey work. Secondary uses of plane coordinates are proving valuable in states where the system has been adopted. In Maryland, the State Police use coordinates in designating any point in the State. Utility companies find the system invaluable in locating stations and transmission lines. Maps carrying coordinate grids facilitate such location work.

The Commonwealth of Pennsylvania legally adopted the Plane Coordinate System in 1937, the Department of Internal Affairs being designated to administer the system. Further action, however, has not been taken to place it in operation. Neither technical personnel nor funds necessary for the successful institution of the system have been made available.

The effective application of the Plane Coordinate System will be a progressive step in the history of surveying and mapping within the State. The system is vital to better engineering practice. We have digressed from topographic maps in discussing the Plane Coordinate System and its status in Pennsylvania; let us return.

Early Mapping in Pennsylvania

It is very interesting to note the importance of topographic maps in the history of Pennsylvania's Geological Surveys, of which the present Survey is the fourth. The First Pennsylvania Geological Survey, under H. D. Rogers, functioned discontinuously from 1836 until 1854. The work of this earliest survey was severely hampered by the lack of base maps, topographic and otherwise.

The Second Geological Survey (1874-1887) produced voluminous reports on Pennsylvania's geology and mineral resources, but the practical value of much of the work was limited because of the lack of topographic maps. This deficiency was clearly recognized by the Second Survey, for topographic maps were prepared by this Survey to facilitate mapping of certain mineral deposits, especially portions of the coal fields. The year 1885 marked the first cooperative topographic mapping effort in Pennsylvania. In this year the U. S. Geological Survey, assisted materially by A. E. Lehman of the Second Survey, mapped the Fairfield Quadrangle in Adams County.

A demand by the public for topographic maps and geologic mapping led to a revival of the Geological Survey in 1899, when the Topographic and Geological Survey Commission was established. Until it was succeeded by the present, or Fourth Geological Survey in 1919, the Commission Survey acted as an agent for the State in sponsoring cooperative topographic and geologic work in Pennsylvania by the U. S. Geological Survey. The year 1900 marked the beginning of fifty-fifty cooperation with the U. S. Geological Survey in topographic mapping. Pennsylvania has continued to cooperate on this basis with the exception of the years 1916-17-18, and is exceeded only by New York in the duration of cooperative topographic efforts.

Demands for topographic mapping have increased over the period of activity of the present Topographic and Geologic Survey which was instituted in 1919. By virtue of the long period of cooperative mapping in Pennsylvania, nearly the entire area of the State is covered by topographic maps. Even so, Pennsylvania is behind the neighboring states—New York, Ohio, West Virginia, Maryland, and New Jersey—which have completed coverage of the entire state. This emphasizes the need for an accelerated mapping program.

The Temple Act

Topographic mapping in the United States was a vital issue to many, especially engineers, who felt the progress of this mapping during the first 20-odd years of the present century was far too slow. World War I found our topographic map coverage grossly inadequate. As a result, the combined engineering societies of the country formulated a 20-year plan to provide for the completion of topographic mapping of the entire United States. The plan was introduced to Congress in 1924 as the Temple Act, being championed by Congressman Temple of Pennsylvania. The bill was approved by Congress, but unfortunately did not get beyond the authorization stage, so mapping of the United States by the U. S. Geological Survey continued at the same slow rate. Another plan aimed at completion of topographic mapping of the country was "The National Mapping Plan" proposed by the National Resources Board. This plan did not get Congressional approval when first proposed in 1934, nor in 1939 when the Secretaries of War, Commerce, and Interior urged its adoption.

A New Era in Mapping

As early as 1904, the U. S. Geological Survey was experimenting with photographs as an aid to mapping. To hasten mapping of the Territory

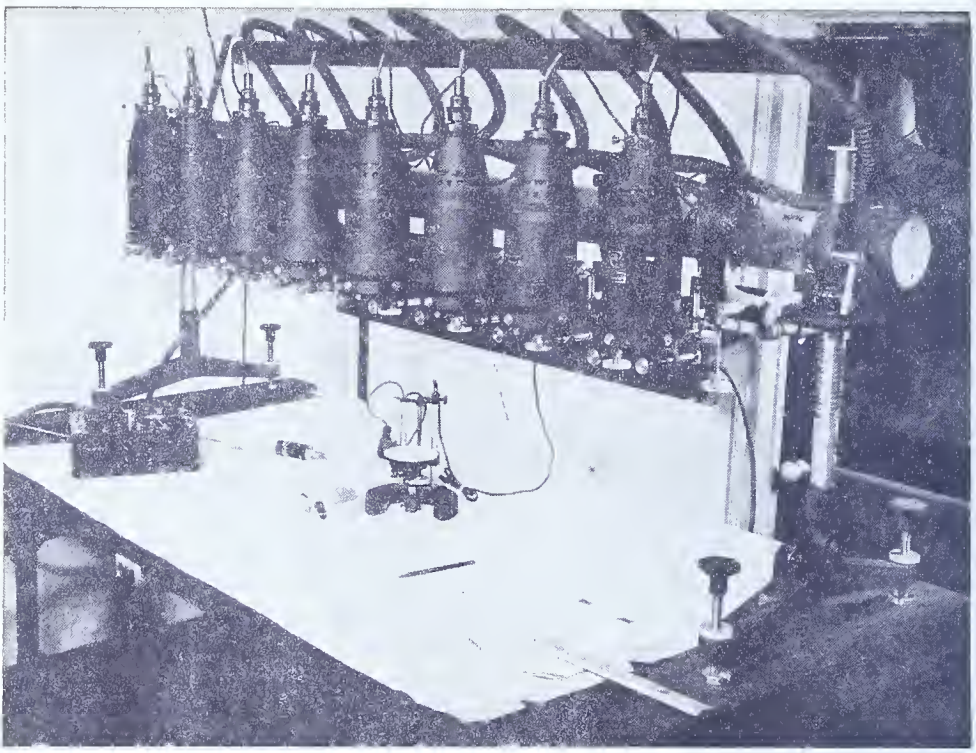

Figure 9. The Multiplex Aeroprojector, used to translate aerial photograph data into topographic maps. This machine, which is used by the U. S. Geological Survey, is one of several stereo-plotters currently being used in the preparation of contour maps. Photograph by courtesy of the U. S. Geological Survey.

of Alaska, members of a Survey party employed photographs taken with a panoramic camera in the compilation of a large-scale reconnaissance map.

Though aerial photography was under development during World War I, it was not utilized in the war-accelerated mapping program. Shortly thereafter, however, the U. S. Geological Survey created the Section of Photographic Mapping necessitated by a cooperative project, mapping the Republic of Haiti, in which aerial photographs were employed. In the execution of this project, the Survey was introduced to the many new problems in map-making with the aid of aerial photographs. In the 1920's, the use of photographs in topographic mapping advanced rapidly, but the plane table and alidade were still responsible for the bulk of the completed mapping. The Survey was continually experimenting with photogrammetric equipment and methods.

The real turning point in mapping methods came with the creation of the Tennessee Valley Authority. In 1934, the U. S. Geological Survey was called upon to map an area of 40,000 square miles for TVA. To do the job quickly, the Survey decided to use aerial photographs, employing the multiplex aeroprojector (Figure 9) to reproduce the topography from the photographs with minimum ground control. Results by the multiplex

method were so satisfactory that the method was adopted by the Survey and is now used in the preparation of most topographic maps. The multiplex aeroprojector, a German development, and one of a number of plotting instruments, has proven most satisfactory and economical in the preparation of 1:24,000 scale maps by the U. S. Geological Survey. Experiments with other equipment continue, however, as the Survey pursues its mapping aims.

Expanded Needs

World War II brought an unprecedented demand for topographic maps, both for military and civilian pursuits. It has been estimated that 130 square feet of charts or maps was provided for every soldier. The War Department created the Army Map Service to accelerate the production of domestic and foreign maps. Many mapping experts from the U. S. Geological Survey as well as other map-producing agencies created a nucleus about which the Service was built. In addition, many personnel were trained completely. The U. S. Geological Survey's trimetrogon process of reconnaissance mapping pioneered in Alaska, developed jointly with the Army Air Forces, and made noteworthy contributions to world-wide small-scale mapping. Many amazing feats of map-making were accomplished by the Army Map Service with full cooperation of other agencies.

In Pennsylvania, a number of quadrangles were remapped or revised by the Army Map Service during the period when new personnel were being trained for their rapidly-expanding program. The resulting maps, though made by the latest methods, showed the inexperience of the personnel, the effects of undue pressure to complete the maps, and lack of adequate field check. For the most part, these maps, though superior in some respects, do not measure up to present standards of map accuracy.

Post-War Demands Heavy

With World War II behind us, we are in a period of nation-wide reorganization. Topographic maps are considered vital to this reorganization, both by industry and government. Again, the U. S. Geological Survey has been requested to submit a 20-year Mapping Plan aimed at completion of adequate map coverage for the United States. This plan has not as yet been adopted, but, in response to the cry for more and better maps, Congress has increased considerably the funds available for topographic mapping by the U. S. Geological Survey.

Some twenty States, including Pennsylvania, are now appropriating money for cooperative topographic mapping. This cooperation is usually on a fifty-fifty basis, with the State supplying one-half the funds and the federal government one-half. The maps are made and distributed by the U. S. Geological Survey.

Pennsylvania has a forward-looking plan for topographic mapping. With the Commonwealth almost completely covered by U. S. Geological Survey topographic maps, the State Planning Board undertook an appraisal of topographic maps in the State. It was found that many maps, especially those produced early in the present century, were inadequate. The Planning Board evolved a priority system to guide remapping of these areas.

We have related briefly some of the highlights in the development of topographic mapping within the United States. Starting with the mapping of uncharted western frontiers, the U. S. Geological Survey has evolved into one of the finest, if not the finest, mapping organization in the world. From topographers preparing maps from field notes to the present-day photogrammetrist using the multiplex, the Survey has constantly sought to produce more and better maps more economically. The 7½-minute quadrangle, 1:24,000 scale, maps being produced today are documentary evidence of this evolutionary achievement. The U. S. Geological Survey has been instrumental in effecting a code of standards for map accuracy. This, together with rapid developments in photogrammetric and other map-making methods, assures us of high-quality topographic mapping in the future.

Part 3

Topographic Map An Aid To Advancing Civilization

MANY people have come to know and use topographic maps of the United States Geological Survey for pleasurable pursuits such as hunting, fishing and vacationing. Few, however, fully realize the tremendous value of these maps in the planning and execution of projects essential to our modern way of life. Vitally dependent upon topographic surveys are locations for highways, railways, dam sites, industrial plants, telephone and electric lines, radio transmission stations, airports, and many other construction projects. Adequate topographic maps are essential to intelligent municipal and broader governmental planning. Topographic map coverage is considered of prime importance in facilitating the work on flood-control, irrigation, soil conservation, soil classification, and reforestation projects. The maximum development of mineral resources very often reflects the availability of maps showing topography. In military tactics topographic maps are of paramount importance.

Highway Planning

One of the most important uses of topographic maps is in highway planning. In one instance a highway was to be constructed between two points sixteen miles apart. A route for the highway was chosen following the completion of three field location surveys at a cost of $5,000. Before construction, however, an alternate route was developed on the basis of a topographic survey that cost $2,200. The highway was constructed along this alternate route at a saving of $200,000 over that route developed by the field location surveys. This case serves to illustrate the savings which may result from use of topographic maps in highway planning.

Special topographic maps with a five-foot contour interval have been prepared along the right-of-way of the eastern extension of the Pennsylvania Turnpike, now under construction. These maps were instrumental in determining the final alignment of the Turnpike. This topographic survey was completed for the Pennsylvania Turnpike Commission by a commercial topographer, since the U. S. Geological Survey topographic maps covering the area were, for the most part, out-dated and badly in need of revision. However, the cost of the new topographic survey will be saved many times over by locating the route to minimize property damage and construction costs.

In one pre-war year, $500,000,000 were spent for the construction of highways in the United States. Highway engineers estimate that $97,500,000 could have been saved in preliminary surveys and construction costs had topographic map coverage been adequate. In this case, the lack of topographic maps may be directly translated into a loss in tax money.

Railroads

The chief engineer of one railroad saved $85,000 by changing the route of a rail line after examining a topographic map. This $85,000 is a mere pittance when compared with the estimated $100,000,000 the railroads of the United States would have saved in preliminary surveys alone had topographic maps been available. No doubt the savings in construction costs would have reached an almost astronomic figure. To prepare a modern topographic map of a 15-minute quadrangle (four 7½-minute quadrange maps; scale 1:24,000) costs somewhat over $38,000. Civil engineers of the railroads of the United States have estimated that $28,000,000 per year in operating expenses could have been saved had the curves and grades been reduced. Topographic maps, had they been available, would have contributed greatly in effecting this tremendous annual saving. The estimated saving in operating costs for one year alone could pay for the topographic mapping of an area almost four times that of the Commonwealth of Pennsylvania.

Utilities and Radio-Television

Seeking economy of installation and efficiency of maintenance, engineers for utility companies are constantly guided by information gleaned from available topographic maps. Power lines are routed to obtain the maximum advantage of topography. In recent years, petroleum pipe lines and coaxial telephone cables crossing Pennsylvania have been planned and laid with great savings in time and money because of existing United States Geological Survey topographic map coverage. Economies in installation and maintenance effected by the use of topographic maps may be passed on to the consumer in the form of lower rates and better service.

In the post-war period, the United States Geological Survey has been swamped by requests for topographic maps from applicants seeking a license to operate frequency modulation or television stations. Both FM and television waves, unlike standard broadcast waves, travel effectively only in a straight line. Unless the station is placed on a high point, these waves may bump into hills and be cut off, thus reducing the effective transmission range of the station. For this reason, the Federal Communications Commission ordered that application for FM and television stations be accompanied by maps showing the elevation of all hills within a ten-mile radius.

Industries Depend on Topographic Maps

It is extremely difficult to appraise the great value of topographic maps in industrial development. It is likely, however, that the advantages of these maps in the realization of industrial development would alone be sufficient to justify modern state-wide topographic coverage. Engineers have estimated that as much as 70 percent can be saved on preliminary surveys in the selection of industrial sites if topographic maps are available, not to mention the advantages of a properly chosen site once the industry is established.

Those interested in the development of greater industrial wealth of a city, county, or the State, will be particularly impressed with one specific example of the need for adequate topographic maps. A promising district

in one of the Southern States lost $10,000,000 in new industries because topographic maps for planning purposes were not available to the prospective manufacturers. This is but one of many similar instances. Confronted with the selection of one of several plant sites of generally equal desirability, industrial planners are most certain to give more attention to the site on which they can visualize their plant layout. This would be the area covered by the topographic map. A state alert to increasing its industrial wealth must anticipate the continuing demand for more and better topographic maps.

Turning from topographic maps for the moment, there is also a serious need for a much expanded knowledge of the full groundwater potentialities of possible industrial areas, if a state is to foster the maximum utilization of its resources. Availability of adequate groundwater is more and more important in the localization of industrial plants. Nothing would be more welcome to many manufacturers than an invitation to establish plants in areas of undeveloped potential water supplies.

Effective Conservation Dependent on Maps

The whole future economy of the United States is dependent upon conservation of our natural resources. Gone are the days of wasteful plenty. Our country is moving into an era which, out of necessity, demands the maximum utilization of our remaining resources with a minimum of wastefulness. Flood control, soil conservation, forestry, irrigation, and mineral development represent important fields of conservation. From all of these, and others too, there is a concerted plea for more and better topographic maps.

The first systematic topographic mapping in the United States was undertaken by the United States Geological Survey out of necessity. In early surveys of the west, as we learned in the preceding chapter on the history of topographic mapping, it was necessary to provide adequate maps on which geologic data could be recorded. This demand resulted in the formation of the Topographic Branch of the United States Geological Survey. The topographic map is considered a most essential tool by the geologist, for geology often finds expression in topography. The accuracy of geologic mapping is frequently dependent upon the quality of available topographic maps. Good geologic mapping is a prime requisite in efficient and thorough development of mineral resources, so the significance of adequate topographic maps to the mineral industries is clearly evident.

One western state is about to embark on a 15-year program of mineral development, which involves millions of dollars worth of minerals over thousands of square miles. Topographic maps are considered a must to the success of this undertaking. Oil companies, spending millions each year prospecting for new reserves within the United States, decry the lack of topographic maps over large areas of the country.

On the other side of the ledger, many millions have been saved in mineral prospecting and development in areas where these maps are available. Study of topography often supplies the key to the geology of mineral occurrences. In the hands of mining engineers, topographic maps may effect tremendous savings in the installation of efficient mining methods, often spelling success to an otherwise doomed venture. In Pennsylvania, topographic maps have long been used to advantage in prospecting for petroleum resources. Coal, clay, limestone, and sand producers have also profited greatly from existing map coverage.

The importance of topographic maps in flood control work is obvious. Without accurate data on the areal extent and character of drainage basins, flood control measures cannot be intelligently planned. The cost of topographic maps to serve as a base for planning control measures in a given drainage area would represent but a small fraction of the property damage which can result from but one serious flood.

Soil mapping and soil erosion control are receiving increasing attention among agriculturists of today. These conservation projects are seriously hampered when adequate contour maps are not available. Forest conservation is equally dependent upon topographic maps. Conservation of wild life is facilitated by good maps. Topographic maps are also in demand in planning and extending recreational facilities.

Military Needs

In these days of world-wide uncertainty, there is a strong movement toward military preparedness. Topographic mapping has no small part in this movement. Military planners have requested 1,620,000 square miles of topographic maps within the next 20 years to remedy the gross inadequacy of existing map coverage. Topography has always had a profound effect on military tactics. In these days of extremely mobile warfare, this effect has increased many-fold.

Plans for Mapping the United States

To meet the many varied and ever-increasing uses of topographic maps, the United States Geological Survey has set up a 20-year program to complete mapping of the United States and its possessions. Only one-quarter of the total area has been completed today—some 2,700,000 square miles remain. Of the United States proper, it is estimated that 48 percent has been mapped. It is believed that the necessary coverage can be completed at a cost of $400,000,000. The grossness of this amount is dwarfed, however, by the estimated resulting savings of over $5,000,000,000 in planning, construction, and operating costs over a similar period in *but three fields*—highway, railway, and industrial. It remains to be seen if Congress will foresee the ultimate economy of this program and provide for its realization.

Status of Mapping in Pennsylvania

In Pennsylvania, topographic maps are available for all of the State, except for eight 15-minute quadrangles in the north-central portion of the State. Maps of this area are now being prepared and will be published as 7½-minute quadrangles (four 7½-minute quadrangles to a 15-minute quadrangle area) to a scale of 1:24,000. A 15-minute quadrangle embraces an area of approximately 225 square miles.

When first topographic coverage of the Commonwealth is complete, we will lack eleven 15-minute quadrangles of having complete coverage at the 1:62,500 scale. With the recent adoption of the larger scale maps, four 7½-minute quadrangles have been published in place of the 15-minute maps. Conversion of the 7½-minute maps to the 15-minute map is merely a problem of reduction and redrafting. The 1:62,500 series is valued as a base for regional compilation of data by many individuals,

agencies, and industries. The Pennsylvania Topographic and Geologic Survey is, therefore, in favor of the early completion of state-wide coverage by 15-minute quadrangles.

Completion of the unmapped sector will not mark the termination of topographic mapping in Pennsylvania—far from it. Systematic topographic mapping of quadrangles began in 1885. Many of the early topographic maps were produced by reconnaissance methods; the resulting maps do not measure up to current standards of accuracy. In many areas new roads, new urban and rural developments, and other man-made changes render the culture of the old maps quite unsatisfactory, especially for engineering and industrial purposes. The need for more accurate topography and up-to-date cultural revision is obvious. A survey of Pennsylvania's topographic mapping needs, published by the State Planning Board in 1945[1], indicates that almost one hundred of the 15-minute quadrangle maps covering Pennsylvania and its bordering areas are inadequate. This same survey established a priority system to guide the remapping of these areas. Already this remapping program has been started in the metropolitan areas of Philadelphia and Pittsburgh.

During World War II a number of Pennsylvania quadrangles were remapped by the United States Army, Corps of Engineers. These maps were hurriedly produced by inexperienced personnel and are, for the most part, substandard.

The United States Geological Survey, cooperating with the War Department, has completed, in part, the remapping of seventeen 15-minute quadrangles in northeastern Pennsylvania. The new issue of maps for this area will be published as 7½-minute quadrangles in line with the present trend toward more detailed maps.

In addition to topographic maps of the 7½- and 15-minute quadrangle areas, there has long been a need for a complete topographic map of the Commonwealth. Topography—Pennsylvania mountains and valleys—has had a great controlling influence on industry, transportation, population, and many other developments within the State. A true perspective of this influence may be gained only by careful study of these controlling features. A topographic map of Pennsylvania to a scale of 1-inch equaling 3 or 4 miles would find unlimited application, ranging from classroom instruction to long-range state-wide industrial planning. With topographic coverage of the State nearing completion, this map is within the sphere of practical realization.

Topographic Mapping Policy

It has been shown in this article that tremendous savings can be effected by the use of adequate topographic maps in the planning and execution of many varied projects. The ultimate advantage in the use of topographic maps can be gained only when accurate, up-to-date coverage is available. It is truly an economy, therefore, to recognize the need for and to provide the best possible topographic coverage of our Commonwealth. Maps which are considered substandard should be replaced by

[1] "Topographic Mapping Needs", Pennsylvania Department of Commerce, State Planning Board, February 1945.

modern maps through a definite priority program of remapping. The goal of the topographic map program within the Commonwealth should not be in terms of a given number of maps, but should be to provide continually the best possible map coverage for all purposes.

In summary it is desirable to outline the salient needs of the Commonwealth with respect to topographic mapping. In order of their relative importance are listed the following needs:

1. Completion of state-wide topographic coverage.
2. Completion of the 15-minute quadrangle (1:62,500) coverage for the entire state.
3. Compilation of a state topographic map to the scale of one inch equals 3 or 4 miles.
4. Remap areas of the state for which present topographic maps are considered inadequate.
5. Revise culture on maps in quadrangles where the topography is considered adequate.

Topographic maps have great value in planning and developing natural, cultural, and industrial resources. In order that the Commonwealth of Pennsylvania may achieve maximum utilization of these resources, it is highly desirable that adequate tools be provided to facilitate the development. Topographic maps number prominently among these tools. It is obvious, then, that those interested in an expanding future for the Commonwealth will recognize the justification for a continuing topographic mapping plan.